Method for making a stressed structure designed to be dissociated

Technical field and prior art

The invention relates to a method of producing a complex microelectronic structure by assembling two basic microelectronic structures, this complex structure being intended to be dissociated. The microelectronic structure concept must be understood hereinafter as including optoelectronic, microtechnological, nanotechnological and nanoelectronic structures.

The technique of transferring a layer from an original substrate to a temporary or final target substrate is increasingly used in microelectronics. This technique has many applications, of which only two will be mentioned here by way of illustrative and non-limiting example. For example, it is used to produce SOI (silicon on insulator) substrates used in particular to produce fast components with low power consumption. It is also used to produce composite substrates that limit costs by avoiding the use of costly bulk substrates. This is the case with bulk silicon carbide substrates, for example.

One prior art method of transferring a thin layer from a source substrate to a target substrate is described in the document FR 2 681 472 and its various improvements (hereby incorporated by reference). It comprises the following steps in particular:

- creation by ionic implantation of a buried weakened region within the source substrate delimiting within that substrate the thin layer to be transferred,
- assembling the source substrate to the target substrate at the free surface of the thin layer, and
- applying thermal and/or mechanical energy to cause a fracture in the source substrate in the weakened region.

A problem can arise if heat treatment is required

to induce some or all of the fracture in the weakened region and the source and target substrates feature materials with very different coefficients of thermal expansion. This is the situation, for example, if it is required to transfer a film of silicon onto a fused silica substrate. Heat treatment can induce high internal stresses within the structure formed by assembling the two substrates, by virtue of the difference in their coefficients of thermal expansion, and these high internal stresses may damage the structure. These stresses can also cause damage at the moment of fracture proper, since at this time the structures immediately relax when they are suddenly dissociated. There is therefore at this moment a sudden jump in the stresses in each structure, i.e. the structure formed of the transferred thin layer attached to the target substrate and the structure formed by the remainder of the source substrate. If its magnitude is too high, this jump can damage at least one of these two structures.

To solve this problem, it would be necessary, at the fracture temperature, to be able to monitor precisely the stresses within the structure formed by assembling the two substrates, in order to maintain them below an acceptable stress level or even to minimize them.

More generally, the problem is that of controlling the stresses within a heterostructure (i.e. a complex structure made by assembling at least two different materials) at the moment of dissociation of the heterostructure when that dissociation necessitates a change of temperature.

Summary of the invention

To solve the stated problem, the invention proposes a method of producing a complex structure by assembling two substrates at respective connecting faces thereof, the structure being adapted to be dissociated in a separation

region, characterized in that, prior to assembly, a tangential stress state difference is created between the two faces to be assembled, this difference being selected to obtain a predetermined stress state within the assembled structure at the moment of dissociation.

The tangential stress state difference between the two faces to be assembled is advantageously selected to minimize the stresses in the separation region at the moment of dissociation.

Thus the invention teaches the intentional generation of stresses in the assembled structure to enable it to compensate the stresses that will subsequently be generated when the temperature is increased to dissociate the structure.

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It is to be noted that, in an entirely different context, the paper by D. Feijoo, I. Ong, K. Mitani, W. S. Yang, S. Yu and U. M. Gösele, "Prestressing of bonded wafers", Proceedings of the 1st international symposium on semiconductor wafer bonding, Science, Technology and applications, Vol. 92-7, The Electrochemical Society (1992) page 230, proposes a method of generating internal stresses within a complex structure with a view to improving the mechanical stability of the structure.

To this end, two structures, in this instance two silicon wafers, are bonded by molecular adhesion under the standard conditions. The complex structure formed in this way is then stressed by curving it by applying a pointer to the center of the structure, which is fixed at its periphery. By curving the structure sufficiently, the bonding interface yields: the two wafers separate and are then rebonded immediately with the new curvature that has been achieved. This separation/rebonding process may be carried out several times, depending on the bonding energy at the interface and the force applied by means of the pointer. When the authors release the stress caused by the

pointer, the complex structure relaxes and stabilizes at a radius of curvature that depends on that obtained at the time of the last separation/rebonding of the complex structure stressed by the pointer. Internal stresses are therefore generated within the complex structure.

However, the internal stresses generated within the structure are not easily adjustable using the above technique because they are dependent on the relative values of the elastic deformation energy of the structure and the bonding energy. Moreover, as the authors indicate, the above method cannot be used for molecular bonding at too high an energy since, under such conditions, the assembled two structures do not separate and, if the pointer is removed within the range of elastic deformation of the structure, the latter reverts to its initial state at the time of molecular bonding. The structure therefore has no curvature and therefore no internal stresses. Now, it is often technologically beneficial to have a high bonding energy, for example to ensure good solidity and a bonding interface of good quality.

The above document is nowhere concerned with monitoring the stresses within the structure linked to a change of temperature.

The technique described in the above document can undoubtedly be used to generate stresses in a complex structure, but this idea is not associated with solving the problem of a heterostructure's temperature behavior. It is therefore only a posteriori that the above document might be seen to have analogies with the invention. In any event, a lack of control of the stresses makes the proposed technique difficult to adjust. It is also limited to structures assembled with limited bonding energies.

The method of the invention does not have the above limitations. The stress state generated within the complex structure depends on stresses generated independently prior

to assembly in each substrate. These stresses are accurately variable (see below). The method is therefore accurately reproducible and variable, enabling the stresses to be monitored (or controlled) as a function of future requirements. The bonding forces between the substrates to be assembled are no longer limited since the complex structure does not have to be separated during assembly by the method of the invention.

In the remainder of this document, the substrates to be assembled are also referred to as basic structures, as opposed to the complex structure formed by assembling these two substrates.

The tangential stress difference between the faces to be bonded of the two basic structures may advantageously be created by deforming (mainly elastically) each of said structures before assembly. A simple and easy technique for generating stresses is to curve these structures.

In a preferred embodiment, the two structures are curved so that the two faces to be assembled are respectively concave and convex. They may be complementary or even respectively spherical concave and spherical convex.

For example, the structures may be curved to generate stresses by applying localized and/or distributed mechanical forces to the structures to be deformed.

In a preferred embodiment, a pressure difference may be created between the two faces of the structure to be curved. The means for producing this pressure difference and for obtaining a basic structure having a face to be assembled include aspirating said structure onto a concave preform of suitable profile selected as a function of that to be imparted to the face to be assembled and on which the structure rests locally at its periphery. Seals may advantageously be provided to improve the seal between the structure and the preform. Aspiration of said structure

into a cavity (without perform) may also be mentioned, the structure resting locally at its periphery on a seal bordering the cavity.

The curved basic structure may be obtained by deforming the above structure between two complementary preforms, one concave and the other convex, with profiles selected as a function of that to be imparted to the face to be assembled. In this case, aspiration channels may be provided on the preform which receives the basic structure to keep the structure curved, once the other preform has been removed. This other preform may advantageously be the other basic structure to be assembled, which has already been curved to the required profile.

Another option is to apply mechanical forces simultaneously to both of the structures to be assembled, for example by deforming the two structures between two preforms with profiles selected as a function of those to be imparted to the faces to be assembled.

It is preferable if:

- mechanical forces are applied to one or more of the substrates by means of a preform consisting of a mold,
- this preform consists of a porous mold, and
- mechanical forces are applied to the substrates with the aid of at least one deformable preform.

The two structures are preferably assembled by molecular bonding, achieving high adhesion forces and an interface of good quality. In this case, before or after creating the stress state difference between the two faces to be assembled, said faces are treated to facilitate subsequent bonding. For example, the treatment may consist in mechanical and/or chemical polishing, chemical treatment, UV/ozone treatment, RIE (reactive ion etching), plasma treatment, or annealing in hydrogen, etc.

According to other preferred features of the invention:

- the substrates are assembled by direct contact, the surface of at least one of the substrates being adapted to prevent air from being trapped between the assembled surfaces,

- at least one of the substrates is pierced,

- that substrate is pierced at its center,

- at least one of the substrates includes at least one dead-end channel discharging at the edge of the substrate,

- the substrates are assembled by means of a flow layer,

- assembly is carried out at a temperature above room temperature,

- the substrates are heated by contact with heated preforms, and

- the preforms are heated to respective different temperatures.

Also, the tangential stress state difference between the two faces to be assembled is advantageously selected so that the prestresses created in this way within the complex structure enable subsequent imposition of specified internal stresses at a specified temperature. The prestresses are advantageously selected to minimize or eliminate the stresses within the complex structure.

The invention also provides a method for transferring a thin layer from a source substrate to a target substrate, comprising the following steps:

- ionically implanting the source substrate through one face thereof to create a buried weakened layer at a particular depth relative to the implanted face of the source substrate, a thin layer thereby being delimited between the implanted face and the buried layer,

- assembling one face of the source substrate to one face of the target substrate to form an assembled structure,

- dissociating the thin layer from the remainder of the source substrate in the buried layer,

the method being characterized in that, prior to assembly, a tangential stress state difference is created between the two faces to be assembled, this difference being selected to obtain within the assembled structure a predetermined stress state at the moment of dissociation.

The tangential stress state difference between the two faces to be assembled is advantageously selected to minimize the stresses in the buried layer at the moment of dissociation. This guarantees the quality of the structures obtained after dissociation.

In a preferred embodiment, the tangential stress state difference between the two faces to be assembled is imposed by curving each of the two substrates to be assembled prior to assembly.

Other aspects and advantages of the invention will become apparent on reading the following detailed description of particular embodiments, which is given by way of non-limiting example. The description refers to the appended drawings, in which:

- figure 1 is a graph showing the evolution of the stresses with temperature at the surfaces of the fused silica substrate within a conventional (silica + silicon) heterostructure,

- figure 2 is a similar graph showing the stresses at the surfaces of the silicon substrate of this heterostructure,

- figure 3 is a diagram of a heterostructure obtained by the method of the invention,

- figures 4 and 5 are graphs similar to those of figures 1 and 2 showing the evolution of the stresses with temperature within a heterostructure stressed by the method of the invention,

- figure 6 is a diagram of one non-limiting

embodiment of the method of the invention,

- figures 7, 8 and 9 show different ways of stressing basic structures to be assembled,

- figures 10A and 10B show from above two examples of producing one of the structures to be assembled in such a way as to prevent trapping air bubbles, and

- figure 11 is a diagrammatic view in section of a pair of deformable preforms.

Detailed description of embodiments of the invention

In the figures to which the following description refers, identical, similar or equivalent parts are identified by the same reference numbers. Also, to clarify the figures, the various items are not represented to a consistent scale.

To illustrate the invention, there will be described by way of non-limiting example a method of transferring a film consisting of a layer of silicon approximately 0.4 µm thick and a layer of oxide approximately 0.4 µm thick from a 200 mm diameter surface-oxidized silicon source substrate 750 µm thick to a 200 mm diameter fused silicon target substrate 1200 µm thick.

The film may be transferred using the following method, employing standard transfer techniques:

- ionically implanting the source substrate to create within that substrate a weakened region that delimits the thin layer to be transferred under implantation conditions known to the person skilled in the art, for example hydrogen implantation at a dosage of approximately 6.10^{16} H^+/cm^2 and at an energy of 75 keV,

- bonding the oxidized layer of the source substrate to the target substrate by molecular adhesion, and

- transferring the thin film by fracture of the weakened region of the source substrate, this fracture

being induced by heat treatment at approximately 400°C, for example, and advantageously being accompanied by the application of mechanical forces.

Figures 1 and 2 respectively show the calculated stresses generated at the respective surfaces of the fused silica and silicon substrates during heat treatment of the conventional complex structure formed by assembling the two substrates. At room temperature, the two substrates are relaxed and there is no internal stress within the complex structure.

Thereafter, as the temperature rises, the structure is progressively stressed: curve 1 in figure 1 shows the evolution of the stresses on the assembled face of the fused silica substrate, curve 2 shows the evolution of the stresses on its free face, curve 3 of figure 2 shows the evolution of the tensile stresses on the assembled face of the silicon substrate, and curve 4 shows the evolution of the tensile stresses on its free face.

This evolution of the stresses with temperature is perfectly familiar to and quantifiable by the person skilled in the art. It is described in the following documents: S. Timoshenko, J. Opt. Soc. am. 11 (1925) page 233/and D. Feijoo, I. Ong, K. Mitani, W. S. Yang, S. Yu and U. M. Gösele, Zhe-Chuan Feng and Hong-du Liu J; Appl. Phys. 54(1), 1983, page 83 "Generalized formula for curvature radius and layer stresses caused by thermal strain in semiconductor multilayer structures". To a first approximation, using continuous elastic theory mechanical calculations, if the materials are considered to be isotropic and the coefficients of thermal expansion are considered to be constant over the applicable temperature range, the evolution of the stresses is approximately linear with temperature. More complex calculations (for example finite element calculations) may be used to refine these results.

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Since silicon has a higher coefficient of thermal expansion than fused silica, as the temperature rises, expansion of the assembled face of the silicon is impeded by the fused silica, which expands less than the silicon. This face is therefore stressed in compression, causing expansion of its free face because of its stiffness. In parallel with this, the assembled face of the fused silica is expanded by the silicon, leading to compression of its free face because of the stiffness of the fused silica.

At the moment of fracture, these stresses are suddenly released. This corresponds to a jump of approximately 100 MPa in the fracture region of the silicon substrate and of 160 MPa at the assembled face of the fused silica.

If they are not controlled, these stress jumps can damage the structures obtained.

On the other hand, according to the invention, the structure is prestressed internally so that at the moment of fracture of the assembled complex structure the stresses are imposed and advantageously below a threshold guaranteeing the quality of the structures obtained after fracture.

Consequently, if the silicon source substrate 5 and the fused silica target substrate 6 are curved prior to assembly with a radius of curvature at the faces to be assembled of the order of 1.2 m, and so that the face to be assembled of the silicon substrate 5 is convex and that of the fused silicon substrate 6 is concave, the structure shown in figure 3 is obtained after assembly with a given tangential stress level at the bonding interface, the assembled face of the silicon being stressed in tension at room temperature and that of the fused silica being stressed in compression at room temperature. The arrows in figure 3 symbolize this stress state at the bonding interface. The line 5' symbolizes a weakened layer produced

beforehand by implantation.

When stressed in this way, the stress level of the complex structure evolves with temperature in the manner shown in figure 4 for the assembled face (curve 7) of the fused silica and its free face (curve 8) and in figure 5 for the assembled face of the silicon (curve 9) and its free face (curve 10).

It may be seen that at the fracture temperature there is practically no internal stress within the assembled complex structure, either in the silicon substrate or in the fused silica substrate. There is therefore no stress jump at the moment of dissociation.

In this example, the internal stresses in the fracture region having been minimized at the fracture temperature, those stresses are no longer operative in the fracture mechanism. This can have only a negligible influence on the thermal budget (temperature-time pair) necessary for the fracture and in this case the same thermal budget is retained. In certain cases it could be necessary to modify the heat treatment time for the fracture to be effected compared to the time necessary for the fracture in the case of bonding without prestressing, for example. If it is a requirement that the heat treatment time should not be modified, it would equally be possible to change the heat treatment temperature. A radius of curvature prior to bonding may then advantageously be selected that is adapted to this new temperature. It may also be beneficial to reduce the internal stresses in the assembled structure, without minimizing them. This is the case, for example, if it is necessary to select the thermal budget necessary for the fracture while at the same time guaranteeing the quality of the structures obtained after fracture. The choice may of course be made to apply either generalized or localized stresses (tension, torsion, etc.) of external origin.

Generating a tangential stress difference between the assembled faces of the source and target substrates therefore limits the stress jumps suffered by the various structures obtained at the moment of dissociation of the assembled structure. If the two substrates to be assembled are bulk substrates and have different coefficients of thermal expansion, the tangential stress state difference between the two faces to be assembled is advantageously selected so that the face of the substrate having the lower coefficient of thermal expansion is stressed in compression relative to the other face to be assembled. The resulting prestressing of the complex structure will then compensate in advance some or all of the future stresses, linked to the rise in temperature, in particular at the dissociation temperature.

Given the selected dissociation temperature and the coefficients of expansion of the materials involved, it will be obvious to the person skilled in the art how to determine the stresses to be generated at the time of assembly.

There are many ways of generating this stress state difference.

Figure 6 shows one embodiment of the method. A first basic structure 11 is deformed by aspirating it onto a first preform 12 of specific shape, for example of spherical concave shape. Aspiration is effected by means of aspiration channels 15 opening onto the surface of the preform. Seals 16 at the periphery of the preform support the first structure 11 and ensure a pressure difference to be obtained between two faces of that structure. Because of this pressure difference, the structure is deformed to espouse the shape of the first preform 12. Because of this deformation, stresses familiar to and quantifiable by the person skilled in the art are generated within the first structure 11 and in particular at its exposed face (here

its upper face).

A second structure 13 is then offered up facing the exposed face of the first structure 11. A second preform 14 with a suitable shape that is advantageously complementary to the shape of the first preform 12, for example of spherical convex shape, is provided to elastically deform the second structure 13 between the second preform 14 and the first structure 11. The arrow represented in figure 6 symbolizes the application of forces to effect the deformation proper. During the deformation, the second structure 13 is progressively deformed into contact with the first structure 11 until it espouses its shape.

The two faces to be assembled having been treated in a manner familiar to the person skilled in the art to enable bonding by molecular adhesion, for example prior to stressing the two structures, bonding is then effected when the two faces coincide.

A complex structure of the type in figure 3 is then obtained formed by the assembly of two stressed structures having at their assembled faces a known tangential stress difference that is imposed by the respective deformations of the two structures prior to bonding.

The person skilled in the art knows how to link the deformation imposed on the structures accurately to the stress levels obtained in the structure and in particular those obtained on the faces to be assembled. He therefore knows, through an appropriate choice of the shapes of the preforms 12 and 14, how to impose a precise tangential stress difference between the two faces to be assembled before bonding and thus to impose stresses throughout the complex structure once assembled. The preforms may be rigid porous or non-porous molds, for example, or deformable membranes.

As shown in figure 7, a variant of the method replaces the first preform 12 with a hollow device 17

having a central cavity 18. The periphery of the first structure 11 then rests on this device with seals 19 sandwiched between them. Aspiration channels 20 reduce the pressure inside the cavity. Adjusting the pressure difference between the two faces of the first structure 11 deforms the first structure 11 to a particular curvature. For example, for a vacuum in the cavity of approximately 0.25 bar, the other face of the structure being exposed to atmospheric pressure, a deflection of 3 mm is obtained in the case of a standard 200 mm diameter silicon wafer 750 µm thick using a seal of 195 mm diameter. The first structure 11 can then be assembled to the second structure 3 in the manner explained above.

Figure 8 shows another variant which consists in deforming the second structure 13 between two appropriate preforms of complementary shape, one (22) concave and the other (21) convex. The convex preform is provided with aspiration channels 24 for holding the second structure 13 in position after deformation and removal of the concave preform 22. The second structure 13 may then be assembled to the first structure 11, which itself has already been deformed (for example in accordance with figure 7), by bonding with the aid of an adhesive, for example.

Another variant assembles the two basic structures by molecular bonding at room temperature and without stress. The assembled structure is then deformed between two complementary molds. After verifying that each of the structures is fastened to one of the molds (for example by aspiration), the assembled structure is separated from the molecular bonding area by any means known to the person skilled in the art. This yields two stressed basic structures that may thereafter be assembled in accordance with the invention. This variant has the advantage of preserving the surface state of the faces to be assembled, for example enabling assembly of the two stressed basic

structures by further molecular bonding.

The assembly of the two basic structures can therefore be effected by molecular adhesion, by bonding by means of an adhesive, or by bonding by means of a bedding layer.

An adhesion layer may be used between the preform and the structure to be deformed or electrostatic or magnetic forces may be used to hold the preform and the curved basic structure in contact.

In a further variant, shown in figure 9, the two structures 11 and 13 are placed face to face without bonding them and are deformed simultaneously between a concave preform 25 and a convex preform 26 with complementary shapes. In figure 9 the arrows show the pressure forces to be applied to cause the deformation. The two structures are then deformed conjointly, a film of air remaining between the two structures. Once the required curvature has been achieved, the air film is evacuated and, because of the forces applied, bonding by molecular adhesion then takes place.

When the second structure 13 is deformed between the first structure 11 and the preform 14, an air bubble may be trapped between the two structures and impede bonding by molecular adhesion. To evacuate this air bubble, it is advantageous to pierce one or both of the structures to be assembled at their center 27, as shown in figure 10A, for example by laser drilling or deep etching of the structure.

An alternative is to provide on one or both structures one or more evacuation channels 28 on the face to be assembled and discharging at the edge of the wafer, as shown in figure 10B. For example, these channels may have dimensions of the order of a width of 100 µm and a depth of 5 µm and be produced by the usual lithography and etching techniques. Aspiration means could be associated

with these channels 28 or the piercing 27 to facilitate evacuation of the trapped air.

Another option may be to effect the deformation and the assembly under a partial vacuum in order to minimize the volume of trapped air, although this method has the drawback of necessitating much harder vacuums to ensure deformation of the structures.

A final option entails placing radial spacers at the wafer periphery and removing them once the central area has been bonded. More generally, any method may be used that enables initiation of bonding between the two structures at their center which then propagates toward the edges. For example, a slight difference in radius of curvature between the two structures could be introduced before bonding to achieve this.

After bonding by the method of the invention, there is obtained, by imposing a tangential stress difference between the phases of the two structures to be assembled, a stressed complex structure in which the stresses at all points are known. When the forces that deformed the two initial structures (mechanical pressure or aspiration by means of a vacuum) are removed, upon the release of the exterior faces of the complex structure, the stresses within that structure evolve, but in a particular manner that is known to the person skilled in the art. Among other things, this evolution is a function of the natures and the thicknesses of the various materials constituting each of the two initial structures and the stress difference at the bonding interface.

The methods described above enable dissociation under controlled stresses of a heterostructure formed of substrates of different materials. These substrates may be thicker or thinner, of simple or composite form (formed of a stack of different layers of thicker or thinner materials), processed or not. The materials concerned are

all the semiconductors, such as in particular silicon, germanium, their alloys ($Si_{1-x}Ge_x$), indium phosphide (InP), gallium arsenide (GaAs), lithium niobate, silicon carbide (SiC), gallium nitride (GaN), sapphire, superconductors such as compositions of the YbaCuO, NbN, or BiSrCaCuO type, for example, or insulators such as, in particular, fused silica, quartz, glasses with different compositions, MgO, all metals such as in particular tungsten, copper or aluminum.

Diverse variants of the foregoing are feasible.

The preforms may be heated to enable hot bonding of deformed intermediate structures. The preforms may advantageously be at different temperatures so that the two intermediate structures have a temperature difference at the moment of assembly.

Bonding the intermediate structures at high temperature also provides control over the internal stresses of the complex structure, in addition to the control already achieved through the controlled deformation of the intermediate structures.

For example, it is then possible to cancel the internal stresses of a complex structure at a given temperature by limiting the deformation of the intermediate structures. For example, it is not wished to deform to a radius of curvature of more than 1.4 m the two intermediate structures consisting of a 750 µm thick silicon wafer 200 mm in diameter and a 1200 µm thick fused silica wafer 200 mm in diameter. These two intermediate structures, deformed to a radius of curvature of approximately 1.4 m prior to bonding, yield a complex structure in which the internal stresses are eliminated at approximately 300°C if bonding took place at 20°C. On the other hand, if the two intermediate structures are bonded at 100°C, the internal stresses of the complex structure are eliminated at 380°C, and thus at a higher temperature without having to deform

further the intermediate structures.

A layer that flows at a certain temperature Tf may be placed between the two intermediate structures. Introducing this flow layer modifies the internal stresses in the complex structure if the heat treatment temperature exceeds Tf.

This minimizes stresses during annealing, for example. Consider, by way of example, a complex structure consisting of a 1200 µm thick fused silica substrate of 200 mm diameter on which there is a 0.4 µm thick film of silicon. Creating the complex structure by means of the invention means that a heat treatment temperature Ttth of 800°C, for example, can be achieved without exceeding the stress level set to preserve good crystal quality in the silicon film (without prestressing the basic structures to form the complex structure, a temperature of 800°C could not be reached without degrading the silicon film). On the other hand, if it is required to raise the heat treatment temperature without modifying the deformation of the basic structures used to obtain the complex structure, there is then the risk of exceeding the stress level that has been set. If there is a layer that flows at Tf, with Tf equal to 800°C, for example, as soon as the heat treatment temperature exceeds Tf the flow layer will flow, thereby relieving some of the internal stresses. Heat treatment can then be carried out at a temperature higher than Ttth without exceeding the internal stress level that has been set.

The preforms may be molds, for example porous molds.

If a pressure difference is used to deform the basic structures or to retain the basic structures on the preforms, it can be advantageous for one of the faces of the basic structures to be at a pressure other than atmospheric pressure, advantageously a pressure higher than

atmospheric pressure. Figure 11 shows by way of example an enclosure 30 containing two preforms 31 and 32 each including a deformable membrane 31A or 32A. Aspiration channels 33 and 34 open onto the surface of these membranes, and are represented here as being tangential. The aspiration or pressurization circuits are represented by double lines.

The aspiration channels maintain the basic structures in their deformed state; the area of the aspiration channels may be limited by subjecting the exposed face of the intermediate structure to a pressure higher than atmospheric pressure (for example a pressure inside the enclosure of 2 bar). Moreover, if the deformable preform is deformed by a pressure difference, a greater deformation can be achieved by increasing the pressure on the exposed face of the basic structure. For example, the preform 31 is at an internal pressure of 1.5 bar, the channels 33 are at a pressure of 0.3 bar, the preform 32 is at an internal pressure of 2.5 bar, and the channels 34 are at a pressure of 0.3 bar. The pressure of the enclosure (2 bar) is between the pressures of the preforms 31 and 32.